The Rural Economy Research Centre

End of Project Report

Project Title: Measuring the Returns to Agricultural and Food Research and Development in Ireland: An Ex Ante Case Study

RMIS No: 5157

Mary Brew and Kevin Hanrahan

Web: www.tnet.teagasc.ie/rerc/

RERC

Abstract

Research provides many of the innovations that are essential to Irish agriculture's ability to sustain and expand economic growth and maintain competitiveness. The agricultural and food research agenda in Ireland and internationally has broadened beyond seeking to just augment conventional productivity and now seeks to provide the means of enhancing the agri-food sector's competitiveness by improving the quality of inputs and outputs, the efficiency of production systems and the development of new products. Recently there has been an increased emphasis on developing Ireland as a 'knowledge based society' and most recently Ireland and more specifically the Irish agri-food sector's development as a "knowledge base bio-economy" has been advocated (Teagasc, 2008). With science, technology and innovation now a major focus of Irish public policy, Ireland is committed to increasing research spending to 3 percent of Gross Domestic Product (GDP) per annum by 2011. Accompanying this greater emphasis on the importance of research there has been significant injections of public funds into the public research systems.

With increased funding arise questions of accountability, i.e. how to prioritise expenditure and measure and evaluate the outcomes of research projects. This project sets out to address what we identified as a key gap in the Irish literature - the evaluation of returns to agriculture and food research that improves the quality of a product, what we have termed demand lifting research. The project sought to address this by evaluating, as a case study, the impact of agricultural research that improves the quality of Irish lamb. If consumers are willing to pay higher prices for what they believe to be a better quality or healthier product then an evaluation of the returns to demand lifting research should be incorporated into the general assessment of the benefits that flow from investment in agricultural and food research.

To date the focus of the evaluation of research benefits in Ireland has been on the returns to supply shifting research (that is to cost reducing research). In general agricultural economists have to date avoided jointly modelling technological improvement and associated changes in product quality. The key features of the comparative static partial equilibrium model developed in this project are linear supply and demand function

specifications, parallel shifts of supply and demand schedules, and the use of the economic surplus methodology to evaluate the costs and benefits of innovations. With the model developed, and using the economic surplus methodology, we can allocate costs and benefits of demand lifting research between producers and consumers.

We use the comparative static partial equilibrium model developed in this project to provide an assessment of the gains to Irish producers and Irish consumers of research that leads to a quality improvement in lamb. This evaluation has been based on a set of assumptions regarding, functional form, elasticity of demand and supply, and the nature of the demand and supply shift related to the demand lifting research innovation.

A series of scenarios were analysed and the results used to assess the impact of demand shifting sheep research. In the first scenario the research based improvement in the quality of Irish lamb was assumed not to be associated with associated any change in the costs of production; in the second scenario the assumed increase in production cost equalled the per kilo premium associated with the improved quality of the lamb produced product. In the third scenario the increase in costs of production were assumed to equal 50% of the premium resulting from the improvement in product quality.

For the purpose of this study the first two scenarios analysed set the upper and lower bounds for the change in economic surplus in the Irish lamb market, we consider the third scenario to be a conservative estimate of the returns to research. In this third scenario the innovations leading to higher quality lamb leads to a gain in economic surplus of €6.405 million per annum.

Given that a large proportion of the improvements in quality will flow from improved genetics it is sensible to consider the surplus as a permanent addition and thus to consider the discounted present value of the additional economic surplus that is attributable to the research induced improvement in lamb quality. The present value of the total sum of benefits over a period of 20 years was estimated to be €79.8205 million.

It was, not possible to estimate the costs involved in research that can be specifically linked to improving the quality of lamb, as this research is not a stand alone project and would have evolved over many years from work at the research centre in Athenry (and earlier work at Belclare). The values for the gains in total economic surplus and the present value of the future stream of benefits from such research can be interpreted as the maximum amount that should be spent in order to achieve the quality improvement.

Measuring the Returns to Agricultural and Food Research and Development in Ireland: An Ex Ante Case Study

Introduction

Agriculture is an indigenous Irish sector with strong links within the economy and a geographic spread throughout the country. As a rural industry, consisting of mainly family farms, it is at the core of many rural communities. Ireland's agriculture also plays a key role in the maintenance of our physical environment. The food industry makes an important contribution to the agricultural sector through its use of indigenous raw materials and through the provision of direct and indirect employment. Therefore, the agri-food sector plays a central role in both the economic and social dimensions of Ireland.

The reform of the Common Agricultural Policy (CAP); the enlargement of the European Union (EU) in 2004 which saw an increase in the number of Member States from 15 to 25; and increasing trade liberalisation as a result of the ongoing World Trade Organisation (WTO) negotiations, are all issues that will have a significant impact on the Irish agri-food sector. This changing environment creates new challenges for the sector including; maintaining the competitiveness of Irish agri-food products; managing resources in a sustainable manner; and meeting consumer demand in relation to food quality and safety (European Communities, 2003).

How has the Irish agri-food industry responded to these challenges? In part; it – like all other economic sectors – has tried to do this through research and development (R&D). High quality research is critically important for a country as it provides the means for the type of innovation essential to an economy in order to sustain and expand economic growth and to maintain competitiveness.

Recent years have seen an increased emphasis on developing Ireland as a 'knowledge based society' – within this, Science, Technology and Innovation (STI) are regarded as crucial to Ireland's continued economic and social development. The change in Irish public policy towards STI is reflected in the significant injections of public funds into the public research system through for example, the Food Institutional Research Measure (FIRM) and the Programme for Research in Third Level Institutions (PRTLI). In addition Ireland as a Member State of the EU has set a target of increasing research spending to 3 percent of Gross Domestic Product (GDP) per annum by 2010. This will:

> "… bring Ireland more into line with the international level of public research funds (public research funding as a percentage of GDP), … Ireland lies behind other OECD countries in evaluating research programmes and scientific fields." (Forfás, 2002:18)

Therefore, the change in public policy towards STI now requires systems to be put in place in order to prioritise expenditure and to measure and evaluate the outcomes of research projects.

There are two principal categories of food research, (a) research which focuses on supply shifting and (b) that which focuses on demand lifting. Supply shifting, that is cost reducing research, has received much attention in the literature - in an Irish context for example see the work of: Boyle, 1986; Boyle and Ryan, 1992; Boyle, 2002. Boyle (2002:5) states "most of the extant analyses of research impact focus on the supply-side effects". Demand lifting, that is quality improving research, has received little attention but consumers, in particular within the EU, are increasingly demanding safe, high quality food. Furthermore the current EU food production strategy places significant emphasis on added value attributes such as food quality (European Communities, 2003).

This project addresses this key gap in the Irish literature on the evaluation of returns to research, i.e. it is concerned with the evaluation of returns to agriculture and food research that improves the quality of a product. It illustrates the model developed through an *ex ante* case study of the returns from agricultural research that improves the quality of Irish lamb**.**

It is not easy to identify the consequences of investments in agricultural research and development. However, Alston and Pardey (1996:162) maintain that

> "An economically rational rural research policy requires an understanding not only of the determinants of the total costs and benefits of private-and public-sector agricultural R&D, but also of the distribution of those costs and benefits among different groups,"

The commodity market model provides the basic framework for the evaluation of the economic impacts of agricultural research. Total benefits are obtained as the sum of producer and consumer benefits, however as Alston and Pardey (1996:126) note

> "an accurate assessment and clear understanding of the measurement issues is central to any attempt to estimate and correctly interpret the economic effects of agricultural research and development."

The model developed in this project also allows for the consideration of the distribution of the benefits from research among different interest groups in society. Vertical disaggregation allocates the producer surplus across the different stages of a multistage production system and horizontal disaggregation allocates the consumer surplus across different markets for a product.

In the remainder of this end of project report we present the a summary of the economic surplus methodology used in evaluating the returns from demand lifting research. This is followed by the the results of the ex ante case study of the returns to Teagasc research on quality improving, that is demand lifting sheep research.

Methodology

Economic analysis provides an understanding of the conditions under which certain groups in society might be expected to gain from research. The concept of economic surplus is the most common approach used for analysing the welfare effects of agricultural and food research. It allows us to generate measures of the streams of benefits attributable to the research (Boyle, 2002; Alston and Pardey, 1996). Although this approach has been criticised, Alston, Norton and Pardey (1995:40) concluded, "for most

purposes, the partial-equilibrium economic surplus model is the best available method to evaluate returns to research".

To date, most analyses of the impact of agricultural research have focused on supply-side or cost reducing research. Productivity gains as a result of agriculture and food research are represented as a reduction in per unit costs and are illustrated as a downward (outward) shift in the market supply curve. Productivity gains can be as a result of either more output being produced with the same amount of total input, or the same amount of output being produced with a smaller quantity of inputs (Alston & Pardey, 1996).

Research may also be motivated by the desire to improve the quality of a product. It is possible to model quality change as an upward shift in the product demand curve. The upward shift in the demand curve reflects the idea that consumers will, *ceteris paribus*, demand more of the quality enhanced product thereby causing an increase in equilibrium quantity as well as in prices at all production levels (provided supply is not perfectly elastic). This form of research has received little attention in the literature. With a few exceptions (see for example Unnevehr, 1986; Lemieux and Wohlgenant, 1989; Voon and Edwards, 1991; Voon, 1992) agricultural economists have avoided jointly modelling technological improvement and associated changes in product quality. Boyle (1986: 60) stated:

> "It is conceivable that research findings may also affect the positioning of the demand curve facing the industry by removing consumer resistance against a product, for instance, but such effects are usually ignored, at least in the literature dealing with agricultural research".

This project is concerned with the economic analysis and evaluation of agricultural and food research that leads to a better quality product, which impacts on the demand for the product. This project uses a multi-market, partial equilibrium commodity model and the economic surplus method to evaluate the gains from demand lifting research. Before outlining the theoretical model used we first introduce the economic surplus method in the context of a simple closed economy commodity model.

The Economic Surplus Method

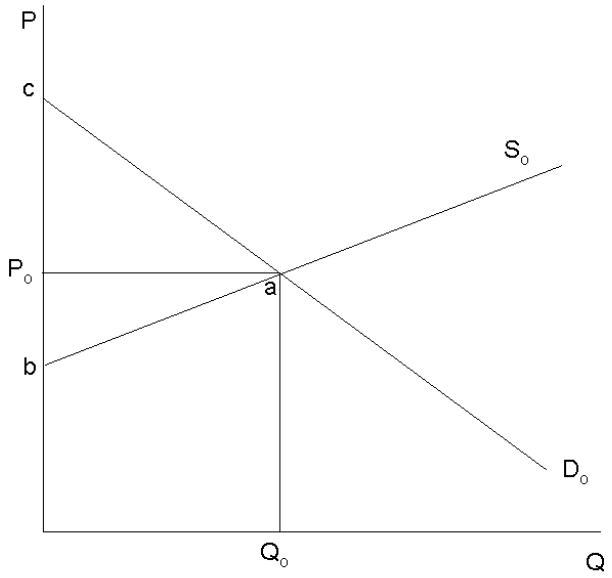
The economic surplus method of evaluation allows us to calculate economic welfare, provided that we have estimates of the market demand and supply curves for the good in question. Changes in the market as a result of, for example, government policy or research will impact on the welfare of the participants in the market. Using the economic surplus method we can with our model of the market for the good in question estimate the effect of such changes on consumer welfare and producer welfare.

Total economic surplus is comprised of consumer surplus and producer surplus. Consumer surplus is a practical measure of consumer welfare: it is the benefit consumers receive from partaking in a market. It is measured by taking the amount that consumers are willing to pay for a good minus the amount they actually pay for it.

Figure 1 shows a typical market supply and demand framework, where the equilibrium price and quantity are $\mathbf{P_0}$ $\mathbf{Q_0}$. Consumer surplus is represented in the diagram by the area above the market price and below the market demand curve up to the quantity consumers buy. In Figure 1 consumer surplus is the area of the triangle $\mathbf{P_0ab}$ when at the price $\mathbf{P_0}$.

Similarly, producer surplus measures the supplier's gain from participating in a market and is measured by taking the seller's cost from the amount the seller is paid for the good. The market producer surplus is the area above the aggregate supply curve and below the market price up to the quantity sold. In figure 1 (at the price $\mathbf{P_o}$), it is the area of the triangle $\mathbf{P_oac}$. Total economic surplus is equal to the sum of producer and consumer surplus, as shown by the area of the triangle **cab**. The price and quantity changes, caused by a shift in the demand curve, can be used to measure the welfare effect of quality improving research. It is measured as the changes in producer and consumer surplus (Alston *et al* , 1995; Boyle, 2002; Perloff, 2004).

Figure 1: Consumer, Producer and Economic Surplus

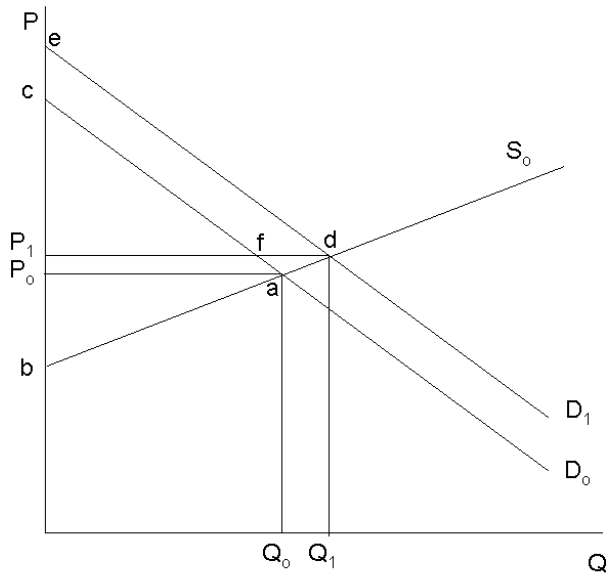


Single Market, Closed Economy, Comparative Static Model

We first illustrate the use of the economic surplus method via a simple model where we only consider a single commodity, in a closed economy. We examine the impact of a demand lifting research innovation. The model, known as the consumer goods characteristics model (CGCM), was proposed by Ladd and Suvannunt (1976) and is based on the work of Waugh (1929). In this model the utility that consumer derive from a good depends on its set of characteristics. Research that augments one or more of a good's characteristics will shift the demand curve for that good upwards, i.e. for any given price, consumers will, other things being equal, demand more of the good following the adoption of the quality improving research based innovation.

Using the simple supply and demand framework presented in figure 1 we represent a demand lifting innovation as an outward and upward shift in the demand curve in figure 2.

Figure 2: The Change in Economic Surplus from a Demand Shift



In the case of an upward shift in demand from $\mathbf{D_0}$ to $\mathbf{D_1}$ a new equilibrium price and quantity for the good of $\mathbf{P_1}$, and $\mathbf{Q_1}$ result. The impact of the research can be measured in terms of the resulting changes in producer and consumer surplus. The change in consumer surplus is then given by the area **ecfd – $\mathbf{P_0P_1}$fa**. This area **ecfd**, is the gain in consumer surplus from increased demand for the higher quality product. The area $\mathbf{P_0P_1}$**fa**, represents the loss of consumer surplus that occurs due to the increase in price for the product.

The change in producer surplus is given by the area $\mathbf{P_0P_1}$**fa + fad**. The increase in price on the initial level of production is represented by $\mathbf{P_0P_1}$**fa** and the triangle **fad** is the gain to producers from the increased demand for the product. The net welfare effect is equal to the sum of changes in consumer and producer surplus, **edac** (Alston *et al* , 1995; Boyle, 2002; Perloff, 2004).

The basic model presented can be extended by considering multiple but related markets, this allows one to deal with issues such as (a) tradable commodities, (b) technological spillovers, (c) impacts on related commodity markets for goods that are substitutes or complements in consumption and (d) multistage production systems (Alston & Pardey, 1996).

In the remainder of this paper we concentrate on one extension of the simple model, its extension to tradable commodities. This implies a relaxation of the closed economy assumption used to this point.

Single Market, Open Economy, Comparative Static Model

When considering the impact of research that improves the quality of an exportable good, the quality improvement shifts the domestic demand and the excess (or *export demand*) for the good.

Figure 3: Single Commodity, Open Economy Model

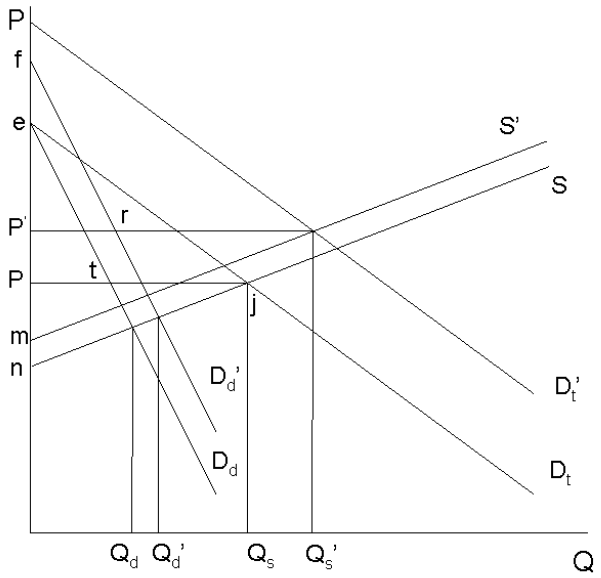


Figure 3 depicts the model for evaluating research benefits from quality improvement for an export commodity. The "without research" domestic demand for the good is shown by $\mathbf{D_d}$. The "without research" total demand curve (the sum of domestic and export demand) is $\mathbf{D_t}$. Therefore, the horizontal difference between domestic demand and total demand is ROW (rest of world) or excess demand. Before research, the domestic and total demand curves are assumed to have a common intercept e on the price axis. The 'without research' supply curve is **S**. As in the basic model, demand and supply curves are assumed to be linear and both demand and supply shifts are assumed to be parallel. In this single commodity model and welfare analysis in related markets are not considered. The model also assumes that the country's entire production of the good being analysed undergoes an identical quality improvement.

If domestic and ROW consumers are willing to pay a premium for the commodity with the improved characteristic, then the domestic and excess demand curves will shift outwards. The domestic demand curve shifts to $\mathbf{D_d'}$ and the total demand curve shifts to $\mathbf{D_t'}$. The size of the shift in the domestic and excess demand curves may differ to allow consumers in the domestic and export market to place separate valuations on the quality improvement.

After the research based demand lifting innovation is adopted the domestic and total demand curves do not have a common intercept on the price axis. The model also allows for an associated shift in supply if the quality improvement also impacts on the supply side of the market. In this model there is a parallel shift in supply to **S'** implying the same absolute increase in costs occurs at all quantities. The price increases from **P** to **P'**. Domestic consumption increases from $\mathbf{Q_d}$ to $\mathbf{Q_d'}$, and the quantity exported increases from $\mathbf{Q_s - Q_d}$ to $\mathbf{Q_s' - Q_d'}$. Domestic producers' surplus increases by the area **P'hm – Pjn**. The change in domestic consumers' surplus is given by the area **P'fr- etP**. The total change in domestic surplus equals the sum of domestic producer plus domestic consumer surplus.

Research costs are not incorporated in this model, but the results from the use of such a model can be interpreted as the maximum amount that could rationally be paid for research to achieve this improvement in quality. The model only allows the welfare changes, as a result of the quality improvement, to be determined for domestic producers and consumers. As

it does not have the demand and supply curves in the rest of the world, the model cannot give estimates of welfare changes in that sector.

The results from the model are influenced by three key parameters: (a) the export demand elasticity, (b) the magnitude of the relative shift in domestic and ROW demand and (c) the relative size of the shifts in domestic supply and total demand for the good being considered.

The Irish Sheep Sector

The Irish sheep sector is overwhelmingly export orientated. Ireland's self sufficiency in lamb, defined as production as percentage of domestic use, has consistently been over 300 per cent.

France is the main export market for Irish lamb, in 2002 it accounted for 68 percent of Irish lamb exports. The Irish sheep meat sector also exports to the UK, Germany, Italy, Portugal, Belgium, Spain and Greece. France is only 47 percent self sufficient in sheep meat. Ireland competes with the UK, New Zealand and Spain as suppliers to the French market. An evaluation of the Irish sheep meat industry carried out by Bord Bia (1996) found that the UK, our main competitor across EU markets, had an "advantage over us in flock size, had a higher number of lambs per ewe, had much higher stocking rates and exported a smaller percentage of its annual output and therefore could select carcasses for export more rigorously". The UK is the main supplier of imported lamb to the French market: approximately 70 percent of the UK's total exports go to the French market (Bord Bia: 2003a). However, the volume of New Zealand chilled lamb entering the French market has more than doubled in the period from 1999 – 2002. This product is going to the higher value end of the market and is consistently available throughout the year (Bord Bia, 2003b: 21). In the same period, imports from Spain also more than doubled from 4,000 to 10,000 tonnes partly because lambs from Spain meet the southern French market demand for lighter lamb carcasses.

The principal criticisms made by French and other overseas buyers of Irish lamb, relate to carcass weight and fat cover. Overfat and overweight lambs are heavily penalised in price and Ireland has traditionally had the reputation of producing a high percentage of lambs that fall into these categories. O'Connell's (1986) sought to identify the factors responsible for

the relatively poor price performance of Irish lamb at Rungis, the wholesale meat market in Paris using the EUROP carcass classification system. The EUROP system describes the economically important characteristics of carcasses in terms that are easily understood by producers, wholesalers and retailers. Conformation (the shape and muscle development of the carcass) is denoted by the letters E, U, R, O, P with E representing the best, and P the poorest. The degree of fat cover is denoted by the numbers 1, 2, 3, 4, 5 in order of increasing fatness. With reference to the French, Irish and British lamb studied, O'Connell found that:

- Irish lamb carcasses were the heaviest and least well conformed;
- Ireland was the only supplier with a large proportion of lamb in fat class 1 (12.4 percent) and fat class 5 (10.1 percent);
- 11.5 percent of carcasses were of conformation P; and
- Only 23 percent of Irish lamb carcasses were found in the optimal weight interval of 17 – 19 kg.

These findings were supported by Davis *et al.* (1988), who found that Republic of Ireland supplies of lamb returned the lowest prices of all imported lamb on the French market. O'Connell questioned the feasibility of closing the quality gap in order to recoup the price premium foregone due to poor quality. He concluded that given the weight, conformation and fat cover of Irish lamb in the sample studied "in the absence of a change in breed structure, it is not possible to profitably close the quality gap between French and Irish lamb" (O'Connell, 1986:11).

The national carcass classification scheme, the EUROP grid, was introduced for lamb in Ireland in 1996. The scheme is operated by the meat plants but monitored by the Department of Agriculture. At that time there was still no evidence of price convergence across EU markets, (see Table 3) and in particular in France, (our main export market), the price difference between home and imported product showed no sign of reducing (Bord Bia, 1996:1).

The Sheep Meat Forum (DAFRD, 1998) noted that the perception of Irish lamb as being of poor quality persisted among buyers in our main export markets. Of particular concern to buyers was the inconsistency in quality at different times of the year. French traders observed that other imported lambs continued to be "better selected, more uniform in quality and fresher than Irish lamb" (DAFRD, 1998). At that time, only 60 percent of lambs

slaughtered in Ireland were graded strictly in accordance with the EUROP Grid. The Forum suggested that a weight criterion in addition to the classification grid be used as a basis for payment at all export approved meat plants and this was to be put into operation in 2000. However, it was 2002 before the national sheep carcass classification scheme was in operation in the vast majority of export-approved plants (DAFRD, 2002c: 67).

Teagasc sheep meat research

Teagasc's sheep research programme is now based at their Athenry Research Centre in Galway. Amongst other objectives the sheep research programme seeks to achieve a better quality product and to increase the competitiveness of sheep meat production. The potential value of lamb output is a function of carcass weight and carcass quality in terms of conformation and fatness. As noted previously, in order to meet the requirements of the export trade, Irish lambs should be leaner and lighter and with better conformation. Teagasc research projects have studied the effects of breeding and management practices on weight, conformation and fat cover. A key study undertaken by Hanrahan (1999), examined the effects of genetic and non-genetic factors on lamb growth and carcass quality. As part of the project, information was collected on carcass weight and carcass classification at export abattoirs during the main marketing period between 1993 and 1997. The study's objective was to develop information on the classification profile of lambs supplied to export plants by producers. It found that:

- Only 60 percent of carcasses from lowland type lambs were within 2 kg of the mean weight;
- 31 percent of carcasses were fat classes 4 and 5;
- 19 percent of carcasses were conformation classes O and P;
- Only 50 percent of carcasses were in the "Target" area, i.e. E2, E3, U2, U3, R2, R3, of the classification grid (1999:v).

These results support the findings of O'Connell (1986) and Davis *et al.* (1988).

The Department of Agriculture, implemented a Pedigree Sheep Breed Improvement Programme (PSBIP) in 1988. The objective of this breed selection programme "is to improve lean tissue growth rate and muscularity in terminal sire (meat) breeds of sheep in Ireland" (DAF, 2002d: 4) that is, to increase carcass lean weight while minimising carcass fat weight increases.

Carcass composition can be improved by selective breeding i.e., by choosing genetically superior animals as parents for future generations (Adams, 2003:1). This can be achieved by: (a) genetic indexing of pedigree breeding stock; and (b) encouraging pedigree breeders to select their flock replacements on the basis of this genetic index. The genetic index put in place by the Department of Agriculture is called the 'Lean Meat Index' (LMI). Genetic evaluation is used to determine which animals are better genetically, based on their own performance and the performance of their relatives. Sustained genetic improvement in the Irish commercial sheep flocks "is essential to maintain competitiveness in the quality Continental lamb market and the financial viability of our sheep meat industry" (DAF, 2002d: 4).

The PSBIP provides pedigree breeders with an index that allows them to exploit genetic differences among breeds and genetic variation within breeds. Hanrahan (1999) found that there was significant within-breed genetic variation for growth, fatness, and carcass conformation. Texel and Suffolk breeds were used to estimate the response to selecting rams on the basis of the LMI values. Selecting rams, within a breed, with a high LMI yields significant increases in lamb growth rate. Progeny of high LMI rams have less fat than lambs by sires with low LMI. When Hanrahan combined the results of this research with previous work, he concluded that Suffolk, Texel and Charollais breeds should be the first options in choosing a terminal sire. Selecting rams within these breeds on the basis of the LMI values give further performance benefits (Hanrahan, 1999:32). Hanrahan carried out a further study on Breed Evaluation in 2001. This study sought to "determine the genetic merits of a wide range of breeds that may be considered for use as sires of crossbred ewes" (Hanrahan, 2001:iii). He found large differences among breed types, emphasising the need for a breeding policy at farm level for the production of flock replacements.

According to Teagasc (2004):

> "Pedigree flocks participating in the Pedigree Sheep Breed Improvement Programme (PSBIP) are now about 15 LMI units better than they were 6 years ago. High LMI rams produce progeny that are 0.5 – 1.0 kg heavier at weaning than low LMI rams. This means that lambs can be drafted about one week earlier. When purchasing rams, it is recommended that (a) they should be sourced from a breeder participating in the PSBIP (b) that they have a high LMI (greater than 110)."

The production of quality Irish lamb can also be promoted by the use of efficient feeding and related farm management systems. A study by Flanagan and Hanrahan (2001) looked at rearing systems for the progeny of early lambing ewes. A trial was conducted to determine if a change in diet could eliminate the difference in carcass weight between the outdoor and early-weaning systems. Consistent with previous results, the effect of feeding system for early lambs, i.e. grazed grass versus early weaning, on carcass weight was significant.

Research at Teagasc has shown that selective breeding and nutritional manipulation can improve the carcass composition and fat cover of lambs. The economic surplus method together with the open economy, partial equilibrium comparative static models outlined earlier can be used to measure the impact of agricultural and food research that could (or has) deliver(ed) such quality improvements. In the remainder of this end of project report the economic model used to evaluate the returns to research that improves the quality of Irish lamb is presented together with the results of our evaluation of the returns to the Teagasc research that improved the quality of Irish lamb.

Ex Ante Case Study of Demand Lifting Agricultural Research: Irish Lamb

As discussed earlier there are two broad methods to achieve quality improvement, improved lamb breeding standards and better management practices. It is assumed that the improvement in lamb quality causes a reallocation of lamb from the lower quality market to the premium quality market. It therefore follows that an improvement in quality will result in a

rise in the proportion of premium quality lamb produced and a corresponding decline in the proportion of lamb of inferior quality.

In our *ex ante* appraisal of a prospective research programme, a model is used to estimate the economic benefits to Ireland from research that improves the quality of an export commodity, in this case Irish lamb.

With a tradable commodity such as lamb an upward shift in the demand curve for lamb occurs in both the home and export markets and causes an increase in equilibrium price at all production levels. The change in the quantity demanded on both the home and export markets is a function of the respective elasticities of demand. The quantity demanded on the home market may increase or decrease depending on the relative size of the shifts and the relative magnitudes of the demand elasticities. These price and quantity changes are used to measure the welfare effects of quality improving research.

Alston and Pardey (1996:66) note that "in deciding how to analyse research benefits for a traded good, the main question is how much detail is warranted". The total benefits from research and their distribution between 'consumers' and 'producers' are sensitive to assumptions about elasticities, the nature of the demand and supply shift and functional forms. The model we use is that described earlier in this report and is a comparative static, partial-equilibrium trading model. It is a partial-equilibrium model because it focuses solely on the Irish lamb industry and treats all other variables as constant. It is a comparative static model as it compares two equilibrium situations, before and after the adoption of quality improving research.

In the partial equilibrium trading model quality improving research is assumed to cause a parallel shift in the demand curve. The commodity supply and demand curves are assumed to be linear. Alston and Wohlgenant (1990), when discussing shifts in supply, suggest "when a parallel shift is used, the functional form is largely irrelevant, and that a linear model provides a good approximation regardless of the true functional form of supply". The vertical shift in demand may be different in the domestic and export markets if the consumers in these markets differ

in their valuation of the quality improvement. An increase in quality may involve an increase in per unit costs of production. Any changes in the costs of production are interpreted as a parallel shift in supply. Research costs are not incorporated in the analysis so results are interpreted as the maximum amount that could rationally be spent in the achievement of the examined quality improvement in lamb.

Parameters and Data Used

The initial equilibrium values for quantities of lamb produced and consumed are taken from data compiled by the Central Statistics Office and are for the year 2000. The figures for prices that apply in the absence of the quality improvement are the actual prices received for Irish lamb, taken from Eurostat's NewCronos database. Price is given in euro per 100 kilograms live weight for fattening lambs. In our model the price paid at the French Rungis market for premium quality imported lamb will be used as the post quality improvement price. This price differential for higher grade imported lamb will be illustrated as a vertical shift in the commodity demand curve. It is possible that quality improvement in lamb will result in increased costs of production for lamb producers. Higher levels of feeding and the purchase of breeding stock of high genetic merit as replacements flock may lead to extra costs for suppliers of premium quality lamb. Increased costs of production will be illustrated as an inward shift of the commodity supply curve.

The Irish own price elasticity of demand for lamb of –1.38 is taken from a recent paper by Hanrahan (2002:25). The long run elasticity of supply of 0.27, is taken from a paper by SAC (2000:186), which evaluated the common organization of the markets in the sheep and goat meat sector. The elasticity of French demand for imports of lamb from Ireland of –3.31 is taken from Hanrahan (2004) who developed an Armington trade model to estimate the elasticity of French demand for lamb from Ireland. In general one would expect the export demand for lamb from Ireland (which in this model is equivalent to the import demand from the rest of the world) to be greater than the domestic demand given the availability of near perfect substitutes in the form of lamb exports from other countries.

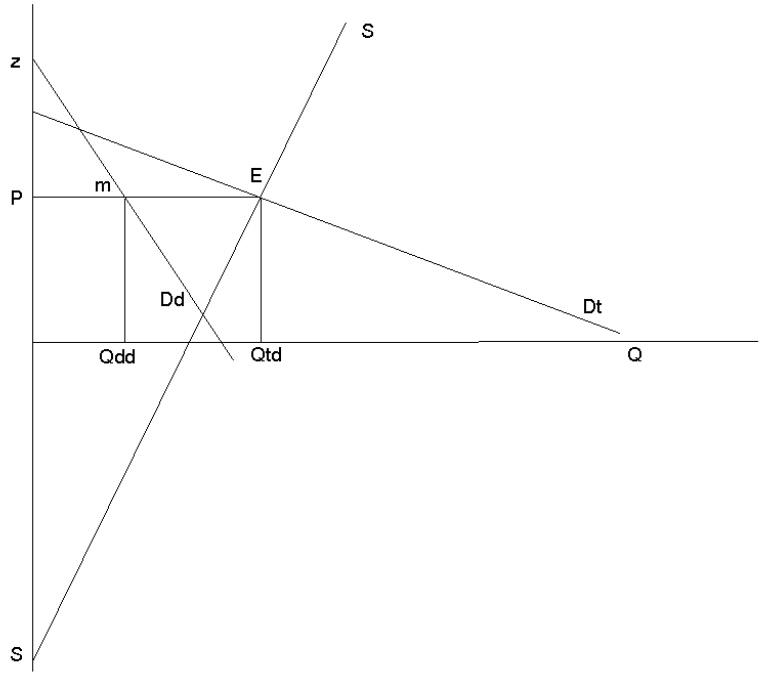
Table 1 Initial Model – Symbols, Definitions, Values and Equations

	Definition	Value	Equation
Q_s	Supply of Irish lamb	83	$Q_s = a + \alpha P$
Q_{dd}	Domestic Demand for Irish Lamb	31	$Q_{dd} = b + \beta P$
Q_{ed}	Export Demand for Irish lamb	52	$Q_{ed} = c + \theta P$
Q_{td}	Total Demand for Irish lamb	83	$Q_{td} = b + \gamma P$
P	Price per 100 Kg	€130.43	
ε	Elasticity of supply	0.27	$\alpha P/Q$
η_{dd}	Elasticity of domestic demand	-1.38	$\beta P/Q$
η_{ed}	Elasticity export demand	-3.31	$\theta P/Q$
η_{td}	Elasticity of total demand	-2.59	$\gamma P/Q$
a	Supply curve slope parameter	0.1718	$\alpha = \varepsilon Q/P$
B	Domestic demand curve slope parameter	-0.328	$\beta = \eta_{dd} Q/P$
θ	Export demand curve slope parameter	-1.3196	$\theta = \eta_{ed} Q/P$
γ	Total demand curve slope parameter	-1.6476	$\gamma = \eta_{td} Q/P$
a	Supply curve interept on quantity axis	60.59	$a = Qs - \alpha P$
b	Domestic demand curve intercept on quantity axis	73.78	$b = Qdd - \beta P$
c	Export demand curve intercept on quantity axis	224.12	$c = Qed - \theta P$
d	Total demand curve intercept on quantity axis	297.9	$d = Qs - \gamma P$
S	Supply curve intercept on price axis	-352.64	$P = (Qs - a)/\alpha$
Z	Domestic demand curve intercept on price axis	224.9	$P = (Qdd - b)/\beta$
D_e	Export demand curve intercept on price axis	169.83	$P = (Qed - c)/\theta$
D_t	Total demand curve intercept on price axis	180.81	$P = (Qtd - d)/\gamma$

The data and parameters presented in Table 1 are used in a partial equilibrium trading model to estimate the economic surplus created by the lamb sector under four different scenarios. First, the initial model is used to measure the economic surplus created by the Irish lamb sector prior to the research induced quality improvement. Second, the change in economic surplus is measured when a research induced quality improvement causes an upward shift in the commodity demand curve. Third, the change in economic surplus is evaluated when the upward shift in the demand curve is fully offset by an equivalent increase in producer costs. Fourth, an intermediary position is examined in which the model incorporates a shift in the supply curve equal to half the shift in the demand curve - that is the increase in the per unit cost of production is half the premium paid for higher quality lamb. Finally, the present value of the future stream of benefits that flow from the innovation are examined.

Initial Model

Figure 4 Irish Lamb Market Equilibrium without Quality Improvement



The model of a small country exporter of lamb (Ireland), is illustrated in Figure 4. Initially the Irish supply curve for lamb is represented by **S**, the domestic demand curve for lamb by $\mathbf{D_d}$ and the total demand curve for lamb by $\mathbf{D_t}$. The total demand curve is the sum of domestic and export demand. The initial equilibrium quantity and price is $\mathbf{Q_{td}}$, **P**. Irish consumer surplus (CS) is determined by the domestic demand curve and is measured by the area **PmZ**. Irish producer surplus (PS) is determined by the total demand curve and the supply curve and is measured by the area **PES**. Using the values given in Table 3 below we can put a monetary value on the total economic surplus generated by Irish lamb production prior to research induced quality improvement.

1) Irish Consumer Surplus (**PmZ**):

$[(Z - P)^* Q_{dd}]/2 = (224.94 - 130.43)^* 31^*(1/2) =$ 1464.97

2) Irish Producer Surplus (PES):

$[(P - S)^* Q_s]/2 = (130.43 - [-352.64])^*(83)^*(1/2) = 20047.57$

3) Total Surplus ($P_m Z$ + PES):

21512.55 which converts to €215.1255 millions.[1]

Returns to Research for Quality Improvement

If consumers in Ireland and the rest of the world (ROW) are willing to pay a premium for higher quality lamb, then research that improves the quality of lamb will raise the domestic as well as the export demand curves for Irish lamb. The size of the demand shifts in Ireland and ROW are measured vertically in terms of the unit value of the commodity (euro per 100Kg). With an increase in quality the domestic demand curve shifts up by v per unit output; the export demand curve by u per unit output; and the total demand curve by w per unit output. The supply curve shifts upwards by x per unit output if there is an increase in the costs of production as a result of the quality improvement. This project examined three scenarios:

1. Research induced improvement in the quality of Irish lamb with no change in the costs of production; outward shift in $\mathbf{D_t}$; outward shift in $\mathbf{D_d}$; no shift in **S**.
2. Research induced improvement in the quality of Irish lamb with an increase in the costs of production equivalent to the premium paid for higher quality lamb; outward shift in $\mathbf{D_t}$; outward shift in $\mathbf{D_d}$; inward shift in **S** (equivalent to shift in $\mathbf{D_d}$).
3. Research induced improvement in the quality of Irish lamb with an increase in the costs of production equivalent to half the value of the premium paid for higher quality lamb; outward shift in $\mathbf{D_t}$; outward shift in $\mathbf{D_d}$; inward shift in **S** (equivalent to half the shift in $\mathbf{D_d}$).

The first two scenarios set the outer bounds for the evaluation of returns to quality improving research in the Irish lamb industry. The third scenario allows for an increase in the costs of production of half the value of the

[1] Price is per 100 Kg and quantity is in tonnes (1000 Kg).

premium paid per unit output for higher quality lamb but could be considered an overstatement of per unit costs

There are two segments within the French lamb market, French lamb and imported lamb and there is an average price differential of 30 percent between French and imported lamb in Rungis (the Paris meat market). In February 2003 the price paid for French lamb was €6.00 kg^{-1} deadweight, while the price for imported lamb was €4.05 kg^{-1}. If this price differential were reduced to 15 percent, i.e. a 50 percent reduction, this would suggest a price of approximately €5.00 kg^{-1} deadweight for imported lamb. This represents a 25 percent increase in price for Irish lamb. The price per 100 kilograms live weight for lamb is €130.43 (Table 4.6) and translating the 25 percent increase in price for quality improved lamb implies an increase of €33 giving a new price of €163.03 per head. Therefore, the vertical shift in export demand denoted by $\boldsymbol{u}$ is estimated at €33.00. One important point to note is that within the imported lamb segment of the French lamb market, Irish lamb trades at a discount due to perceptions of its inferior quality and inconsistency that were discussed earlier. This would indicate that narrowing the French to Irish price differential would perhaps involve a greater absolute price increase. The 25 percent increase as a result of narrowing the gap between the prices paid for imported and French lamb by a margin of 50 percent can thus be considered as conservative in the case of Irish lamb.

The improved Irish price or reduced price differential with the French imported lamb price would reflect the improved carcass conformation that occurs with improved lamb genetics and animal husbandry practices based on Teagasc research. The value of €13 for the vertical shift in domestic demand, denoted by $\boldsymbol{v}$, reflects the price differential between O and R grades of lamb (Bord Bia 2003a). The vertical shift in total demand is $\boldsymbol{w}$ is related to $\boldsymbol{v}$, the shift in domestic demand and $\boldsymbol{u}$ the shift in export demand and has the value €25.53.

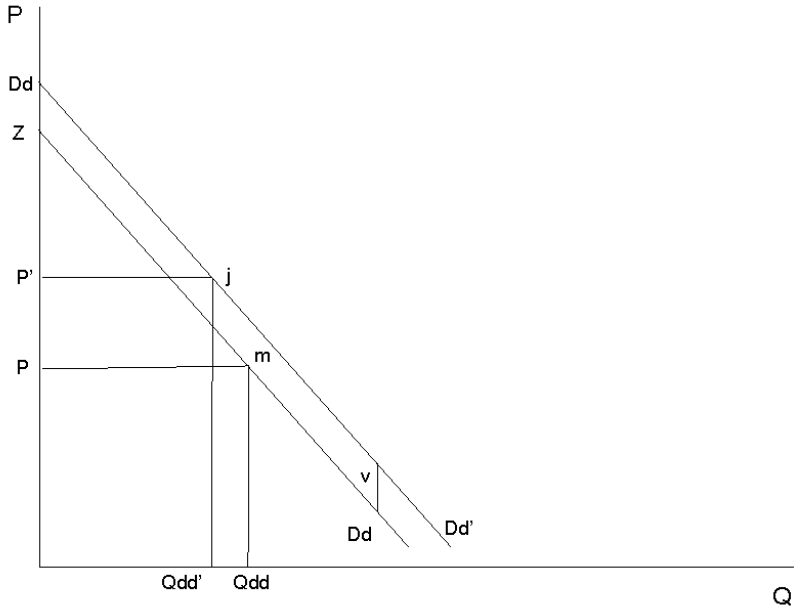
The parameters of the first scenario with no change in the costs of production as a result of quality improvement are outlined in Table 2

Table 2 First Scenario

	Definitions	Values	Equations
v	Vertical shift in domestic demand	€13	
u	Vertical shift in export demand	€33	
w	Vertical shift in total demand	25.53	$(uQ_{ed} + vQ_{dd})/Q_s$
x	Vertical shift in supply	0	
Q_s	Supply of Irish lamb	83	$Q_s = a - \alpha(x - P)$
Q_{dd}	New domestic demand for Lamb	31	$Q_{dd} = b + \beta(v-P)$
Q_{ed}	New export demand for lamb	52	$Q_{ed} = c + \theta(u-P)$
Q_{td}	New total demand for lamb	83	$Q_{td} = b + \gamma(w-P)$
P′	New price when $x = 0$	€130.43	$=P+(\alpha x-\gamma w)/(\alpha-\gamma)$
S′	Original intercept on price axis x = 0	-352.64	$= (Q_s' - a + \alpha x)/\alpha$
D_d'	New intercept on price axis v = €13	224.9	$P = (Q_{dd}' - b + \beta v)/\beta$
E_d'	New intercept on price axis u = €33	169.83	$P = (Q_{ed}' - c + \theta u)/\theta$
D_t'	New intercept on price axis w=€25.33	180.81	$P = (Q_{td}' - d + \gamma w)/\gamma$

Evaluating the improvement in lamb quality with no change in the costs of production, Figure 5 illustrates the change in Irish consumer surplus as a result of the quality improvement. The domestic demand curve shifts up from Dd to Dd′. The price of lamb increases from P to P′ and quantity demanded reduces from Qdd to Qdd′. Consumer surplus after the quality improving research is measured by the area P′jDd′. The change in consumer surplus is therefore equal to the area of P′jDd′, (CS after quality improving research) less the area of PmZ, (original CS).

Figure 5 First Scenario – Outward Shift in Domestic Demand with No Change in the Cost of Production



4) Irish Consumer Surplus (**P'jDd'**):

[(Dd' – P')*Qdd']/2 = (237.94 – 153.03)*(1/2*27.85) = 1168.07

5) Change in Consumer Surplus **(P'jDd' – PmZ)**

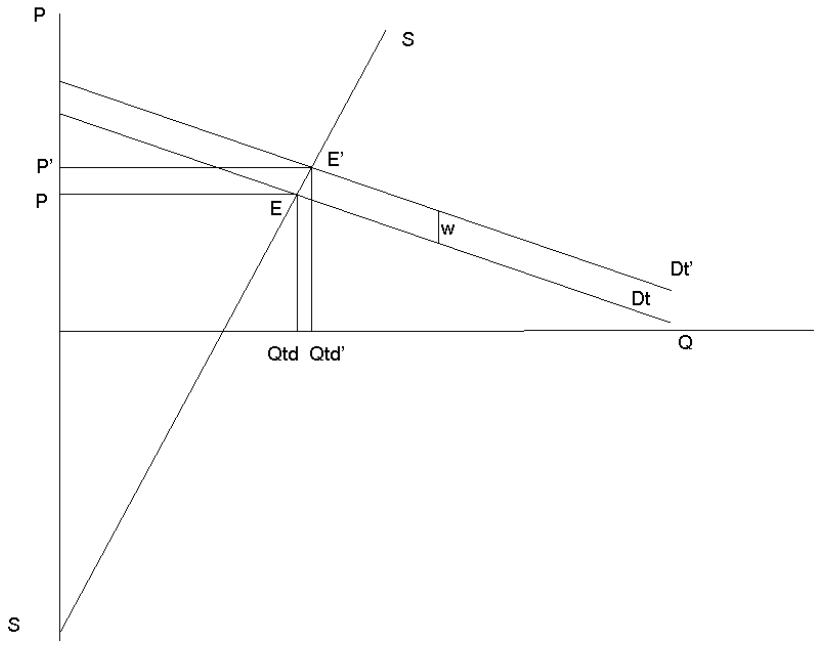
1168.07 – 1464.97 = 296.90

There is a loss in consumer surplus of €2.969millions.

Figure 6 depicts the change in Irish producer surplus. In order to evaluate the impact on producer surplus we look at the change in total demand (where total demand is the horizontal summation of domestic and export demand). With the increase in quality the total demand curve shifts up by *w* per unit output from **Dt** to **Dt'**. Price increases to **P'** and total quantity demanded increases to **Qtd'**. Irish producer surplus after the quality improving research is measured by the area **P'E'S**. The change in producer surplus is therefore equal to the area of **P'E'S**, (producer surplus after

quality improving research) less the area of **PES**, (the initial producer surplus).

Figure 6 First Scenario – Outward Shift in Total Demand with No Change in Costs of Production



6) Irish Producer Surplus **(P'E'S)**:

[(P' – S)* Qtd']/2 = (153.55 – [-352.64])*(86.97)/2 = 22012.38

7) Change in Producer Surplus **(P'E'S – PES)**:

22012.38 – 20047.57 = 1964.80

8) The Overall Change in Economic Surplus =

Sum of changes in consumer surplus (equation 5) and producer surplus (equation 7) = 1667.90

This can be interpreted as an economic surplus gain of €16.679 millions if there is no change in production costs as a result of the research induced quality improvement.

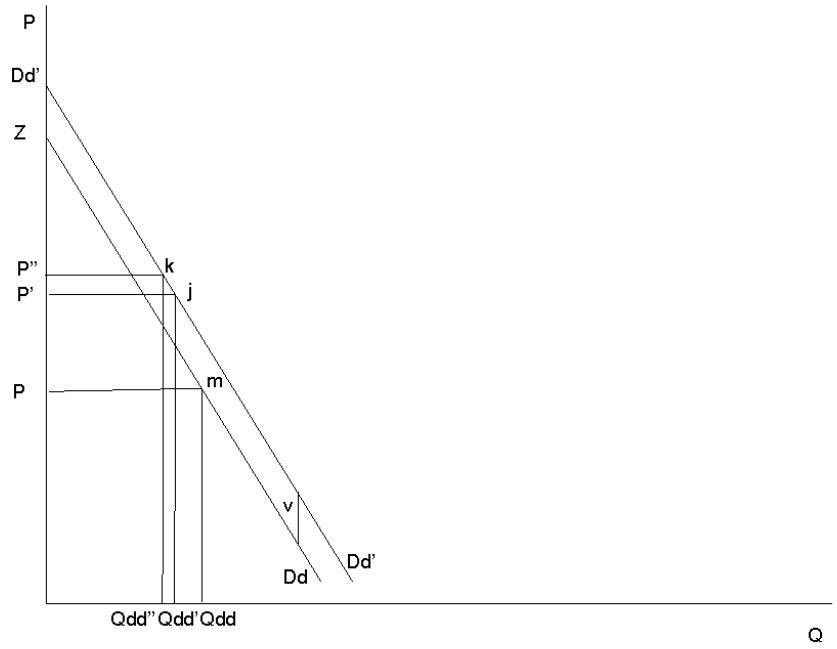
The parameters of the second scenario, which allows for an increase in the costs of production for suppliers of quality improved lamb are set out in Table 5

Table 3 Second Scenario– Symbols, Definitions, Values and Equations

	Definition	Value	Equation
Q_s''	Supply of Irish lamb	83	$Q_s = a - \alpha(x - P'')$
Q_{dd}''	New domestic demand for Lamb	26.89	$Q_{dd} = b + \beta(v - P'')$
Q_{ed}''	New export demand for lamb	61.86	$Q_{ed} = c + \theta(u - P'')$
Q_{td}''	New total demand for lamb	83	$Q_{td} = b + \gamma(w - P'')$
P''	New price when $x = 0$	€155.96	$=P+x$
S''	Original intercept on price axis x = 0	-327.11	$= (Q_s'' - a + \alpha x)/\alpha$

If quality improvement increases the costs of production for suppliers then the supply curve will shift inwards. In this second scenario it is assumed that the inward shift in supply is equivalent to the outward shift in demand that is the increase in production cost per unit output is equivalent to the premium paid per unit output for higher quality lamb. Therefore, price will increase further to **P''** and domestic demand will reduce further to **Qdd''**. Irish consumer surplus is now shown by the area **P''kDd'** (see Figure 7).

Figure 7 Second Scenario – Outward Shift in Domestic Demand with an Inward Shift in Supply



The change in consumer surplus is equal to the area of **P'kDd'** less the area **PmZ** (consumer surplus prior to the research).

9) Irish Consumer Surplus (**P''kDd'**):

[(Dd' – P'')*Qdd'']/2= [(237.94 – 155.96)*26.89]/2 = 1102.29

10) Change in Consumer Surplus (**P''kDd' – PmZ**)

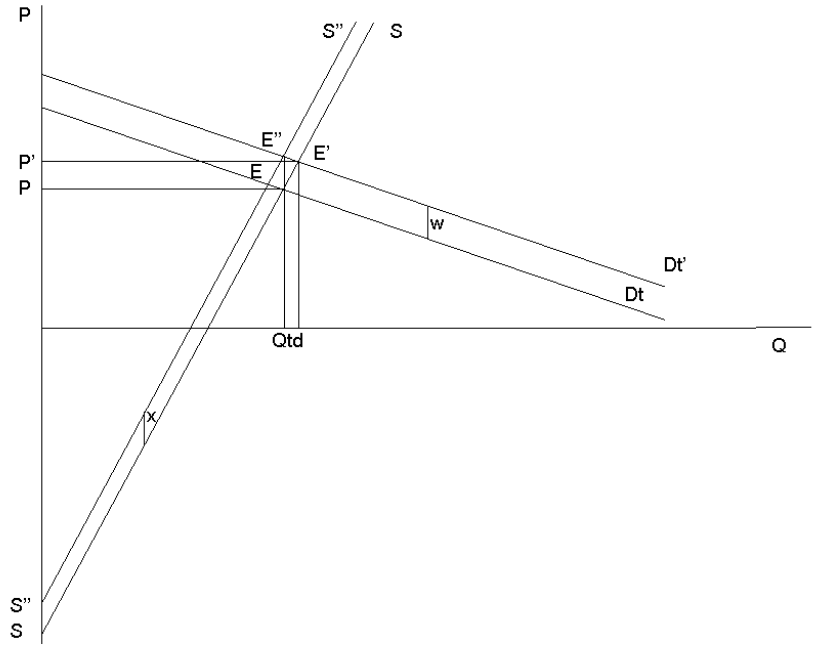
1102.29 – 1464.97 = -362.68

Therefore there is a loss of consumer surplus to the value of €3.6268 millions.

Figure 8 illustrates the change in Irish producer surplus when we allow for an increase in producer costs equivalent to the premium paid per unit output for higher quality lamb on the Rungis meat market. The total demand curve shifts outwards by **w** (€25.53) per unit to **Dt'**. The supply

curve shifts inwards by **x** (€25.53) to **S''**. Price increases to **P''** and quantity reverts to the initial equilibrium level at **Qtd**. Irish producer surplus is now measured by the area **P''E''S''**. The change in producer surplus is then equal to the area of **P''E''S''** less the area of **PES** (the original producer surplus).

Figure 8 Second Scenario - Shift in Total Demand with an Equivalent Shift in the Supply Curve



11) Irish Producer Surplus **(P''E''S'')**:

[(P''– S'')*Qtd'']/2= [155.96 – (-327.11)]*(83)/2 = 20047.57

12) Change in Producer Surplus (P''E''S' – PES):

20047.57 – 20047.57 = 0.00

13) The Overall Change in Economic Surplus =

Changes in Consumer surplus (equation 10) and Producer surplus (equation 12) = -362.68

This implies that there is a loss in total economic surplus of €3.6268 millions if the increase in the costs of production per unit of output is equivalent to the premium paid for the higher quality lamb.

The parameters for the final scenario are set out in Table 6. In this scenario an allowance is made for an increase in the costs of production per unit of output equivalent to half the premium paid per unit of output for higher quality lamb.

Table 6 Third Scenario – Symbols, Definitions, Values and Equations

Q_s'''	Supply of Irish lamb when $x=x''=w/2$	84.99	$Q_s = a - \alpha(x - P''')$
Q_{dd}'''	New domestic demand for Lamb when $x=w/2$	27.29	$Q_{dd} = b + \beta(v - P''')$
Q_{ed}'''	New export demand for lamb when $x=w/2$	63.45	$Q_{ed} = c + \theta(u - P''')$
Q_{td}'''	New total demand for lamb when $x=w/2$	84.99	$Q_{td} = d + \gamma(w - P''')$
P'''	New price when $x=w/2$	€154.76	$=P+(\alpha x''' - \gamma w)/(\alpha - \gamma)$
S'''	Original intercept when $x=w/2$	-339.87	$= (Q_s'' - a + \alpha x)/\alpha$

The following equations measure the changes in consumer, producer and total economic surplus for the third scenario.

14) Irish Consumer Surplus:
[(Dd′ – P′′′)* Qdd′′′]/2= (237.94–154.76)*(27.29)/2= 1134.93

15) Change in Consumer Surplus: (equation 14 – equation 1)
1134.93 – 1464.97 = -330.04

16) Irish Producer Surplus:
[(P′′′– S′′′)*Qtd′′′]/2 =[154.76– (-339.87) *84.99]= 21018.11

17) Change in Producer Surplus: (equation 16 – equation 2)

21018.11 – 20047.57 = 970.54

18) The Overall Change in Economic Surplus:

Change in Consumer (equation 15) and producer (equation 17) surplus= 640.50

This indicates a gain in economic surplus of €6.405 millions in this final scenario, where the increase to the suppliers in their costs of production as a result of supplying a higher quality lamb product is half the value of the premium paid for the product.

Results and Implications

The total economic surplus in the lamb sector prior to the research induced quality improvement is €215.1255 millions. We have looked at three possible scenarios for the evaluation of returns to research in the lamb sector. The first and second scenarios set the outer bounds for the evaluation. The first scenario sets one boundary by assuming no change to suppliers in the costs of production of the higher quality lamb and gives an overall gain in economic surplus of €16.6790 millions. An increase in producer costs equivalent to the premium paid per unit output for higher quality lamb would be the second boundary and this is set out in the second scenario. In this example there is an overall loss in economic surplus of €3.6268 millions. In the third scenario we assume a mid value of half the premium paid for per unit output for premium quality lamb. This gives an overall gain in economic surplus of €6.4050 millions. This could be considered an underestimation of the returns to research induced quality improvement in the lamb industry. Quality improvement can be achieved by the use of efficient feeding and related farm management systems and by selective breeding, i.e., by choosing genetically superior animals as parents for future generations.

Improving lamb breeding standards is considered a cost effective and cumulative method of improving the quality of lamb (Adams, 2003; Simm and Dingwall, 1989). In the third scenario an allowance is made for an increase in the costs of production per unit of output equivalent to half the premium paid per unit of output for higher quality lamb. If we take into consideration that selective breeding influences the performance of an

animal over its lifetime and improvements made in one generation get passed on to the next then the increase in the costs of production per unit output could be considered a probably overestimate. The gain in economic surplus in this scenario was estimated to be €6.405 millions therefore this could be considered a conservative estimate.

By examining the present value (PV) we evaluate the future stream of benefits associated with research induced quality improvement in lamb. However, it is difficult to estimate Teagasc expenditure on research into quality improvement in lamb, as research in this field is an integral part of Teagasc sheep meat research at their Athenry research centre. Quality improvement research is not a stand-alone project. Therefore we can interpret the results as the maximum that should be spent to achieve quality improvement in lamb.

Present Value (PV) involves discounting the steam of benefits over the lifetime of a research programme. A positive number indicates value for money, and the larger the number the better the return. The formula for estimating PV is:

$$PV = B/(1 + r)t$$

where:

- **r** is the discount rate, assumed to be 5 percent as recommended by the Department of Finance (Boyle, 2002:142);
- **B** is the calculated value for annual research benefit, €6.405 million in the third scenario;
- **t** is the number of years, the benefits are assumed to have commenced at the end of 2004, for 20 years until 2024.

The total sum of benefits over the 20-year period would amount to €79.8205 millions.

As noted earlier the model developed in this project can be extended in a number of dimensions depending on the issue of concern. This project focused on a single commodity, lamb in isolation. The model ignores interrelationships in demand and supply with other livestock industries. It assumes that changes in the price of lamb will have no effect on the demand for and supply of other meats and therefore there will be no

feedback effects in the lamb markets. However, when goods are substitutes or complements in consumption, a quality improvement in the lamb market while affecting consumption and price in its own market may also affect consumption and price in related markets. Welfare effects in related markets, (for example, beef, chicken, pork) could be considered by extending the model to a multi-commodity framework.

Economic benefits from a rise in demand for the commodity at farm level will be distributed between different economic agents along the supply chain, such as input suppliers, farmers, processors, retailers, and final consumers. This model developed in this project could be extended to identify research benefits to each of these agents Determining the net economic welfare benefits for processors, producers and consumers requires an economic model that identifies explicitly the multi-stage production process involved.

> "Export market demand for Irish lamb will be largely determined by import demand levels in France and the strength of competition from UK and New Zealand supplies" (Bord Bia, 2003b: 24).

It is important to change the reputation of Irish lamb carcasses as being overfat and overweight given that lamb carcasses that fall into this category are heavily penalised on the export and domestic meat markets. The technologies to improve performance in the Irish sheep sector in terms of carcass conformation and fat cover are readily available as a result of research carried out by Teagasc. It is essential that these technologies be adopted to ensure the future competitiveness of the Irish sheep meat sector (Connolly, 1999:12).

Improving lamb breeding standards across the country can help achieve improvement in quality. Genetic evaluations of breeding animals will facilitate genetic improvement of the Irish national sheep herd. Pedigree breeders can play an important role by supplying breeding stock of high genetic merit for increased lean meat production and low fat production. It is generally accepted that genetic improvement, although relatively slow is a permanent, cost-effective and cumulative method of improving carcass composition. It influences the performance of an animal over its lifetime and improvements made in one generation get passed on to the next. Genetic improvement should therefore form part of the lamb producers'

response to consumer demand (Adams, 2003:1; Simm and Dingwall, 1989:224).

Management practices will also influence the quality of lamb. The expression of genes is influenced by the animals' environment, that is the level of feeding and management practices. For example, a high level of feeding results in good animal performance as it promotes a higher lean tissue growth rate but does not improve the inherent quality of the genes in any way (DAF, 2002a: 6).

In summary, in this project a supply-demand, economic surplus model has been used, in an *ex ante* appraisal of a prospective research programme, to generate measures of the streams of benefits attributable to the demand lifting effects of research. The model has been illustrated by estimating the gains to Irish producers and consumers of research that leads to a quality improvement in lamb.

This evaluation has been based on a set of assumptions regarding, functional form, elasticity of demand and supply, and the nature of the demand and supply shift. Definitions, values and equations used in the three simulations to evaluate the returns to quality improving research in the Irish lamb market have been outlined. Mathematical formulae were then used to measure the changes in consumer and producer surplus from the adoption of quality improving technologies.

We have found that a gain of €6.4050 million per annum would be a conservative estimate of the returns to research for quality improved lamb. In addition, the present value of the total sum of benefits over a period of 20 years was estimated to be €79.8205 million. Unfortunately, it was not possible to estimate the costs involved in research that improved the quality of lamb, as this research is not a stand alone project and would have evolved over many years from work at the research centre in Athenry. The euro values for the gains in total economic surplus and present value of benefits can be interpreted as the maximum amount that should be spent in order to achieve the quality improvement.

To disaggregate the research benefits further would require significantly more information. However, this basic model can be extended vertically, to consider lamb production as a multistage process where on farm production is linked to food processors as well as consumers. It can also be extended horizontally to consider the impact of quality improvement in the lamb market on other agricultural commodities, for example, chicken or beef. One further issue, not discussed in this report, with respect to Irish lamb exports is the ratio of supply to capacity as this also has a bearing on the question of price differentials. The greater the ratio the easier it is for an industry to operate differentials, the lower it is the greater is the need to get throughput irrespective of quality. In the past when demand has exceeded supply, processors have not priced to the EUROP grid in a strict manner. Therefore, producers do not have the incentive to apply appropriate standards to meet a given target carcass weight when drafting lambs for slaughter (Hanrahan, 1999). Processors must operate price differentials for quality if producers are to have an incentive to change the genetic make up of their flock and/ or change their farm management practices in order to improve the quality of lamb.

Bibliography

Adams, L., (2003), Lean Meat Index, Getting Better Quality Lamb More Efficiently, Dublin: DAFRD.

Alston, J.M., G.W. Norton, and P.G. Pardey, (1995), Science under Scarcity, Ithaca: Cornell University Press.

Alston, J.K. and P.G. Pardey, (1996), Making Science Pay, Washington: The AEI Press.

Bord Bia, (1996), The Irish Sheepmeat Industry – An evaluation of market changes underway and recommendations for the future, Dublin: An Bord Bia

Bord Bia, (2003a), Market Monitor, 15th February

Bord Bia, (2003b), Annual Meat and Livestock Review and Outlook 2002/03, at www.bordbia.ie

Boyle, G.E., (1986), 'An Exploratory Assessment of the Returns to Agricultural Research in Ireland 1963-1983', Irish Journal of Agricultural Economics and Rural Sociology, Vol. 11: 57-71.

Boyle, G.E. and M.C. Ryan, (1992), Technological Progress in Irish Agriculture: The Role of the State, Maynooth, Co. Kildare: Maynooth College, Department of Economics.

Boyle, G.E., (2002), The Costs and Benefits of Agricultural Research in Ireland, Seven Case Studies, Cork: Oak Tree Press.

Connolly, L., (1999), Competitiveness of Irish Sheep Production, Athenry: Teagasc Project No. 4016.

Davis, J., N. Prins, C. Nugent and N. Fulton, (1988), The Marketing of Northern Ireland Sheepmeat, Belfast: The Queen's University of Belfast.

Department of Agriculture, Food and Rural Development, (1998), The Sheepmeat Forum, Dublin: DAFRD.

Department of Agriculture, Food and Rural Development, (2002c), Pedigree Sheep Breed Improvement Programme Performance Results for Lambs, Cavan: DAFRD.

European Communities, (2003), New Vision on European Food and Agricultural Research, Luxembourg: Office for Official Publications of the European Communities.

Flanagan, S. and J.P. Hanrahan, (2001), Reproductive Management for Early Lambing Ewes and Rearing Systems for their Progeny, Galway: Teagasc, Project No. 4516.

Forfás, (2002), Measuring and Evaluating Research, Report of the ICSTI Task Force, Dublin: Forfás.

Hanrahan, J.P., (1999), Genetic and non-genetic factors affecting lamb growth and carcass quality, Galway: Teagasc, Project No. 2551.

Hanrahan, J.P., (2001), Breed Evaluation: Performance of Crossbred Ewes, Galway: Teagasc, Project No. 2549.

Hanrahan, K.F., (2002), A Fully Regular Model of Irish Meat Demand, Paper presented at the AES Annual Conference, The University of Wales.

Hanrahan, K.F., (2004), An Armington Trade Model – French Consumer Demand for Irish Lamb, A Working Paper.

Ladd, G.W. and V. Suvannunt, (1976), 'A Model of Consumer Goods Characteristics', American Journal of Agricultural Economics, Vol. 58 (3): 504-510.

Lemieux, C.M. and M.K. Wohlgenant, (1989), 'Ex Ante Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine

Somatotropin', American Journal of Agricultural Economics, Vol. 71(4): 903-914.

O'Connell, J, (1986), An Analysis of Carcase Lamb Prices on the Paris Market, Dublin: Department of Agricultural Economics, University College Dublin.

Perloff, J.M., (2004), Microeconomics, Boston: Pearson, Addison, Wesley.

SAC, (2000), An Evaluation of the Common Organisation of the Markets in the Sheep and Goat Meat Sector, Ayr: SAC.

Simm, G., and W.S. Dingwall, (1989), Selection Indices for Lean Meat Production in Sheep, Amsterdam: Elsevier Science Publishers.

Teagasc (2008) Towards 2030: Teagasc's role in Transforming Ireland's Agri-Food sector and the wider Bioeconomy. Oakpark, Carlow: Teagasc.

Unnevehr, L.J., (1986), 'Consumer Demand for Rice Grain Quality and Returns to Research for Quality Improvement in Southeast Asia', American Journal of Agricultural Economics, Vol. 68(3): 634-641.

Voon, J.P. and G.W. Edwards, (1991), 'Research Payoff from Quality Improvement: The Case of Backfat Depth in Pigs', Journal of Agricultural Economics, Vol. 42(1): 66-76.

Voon, J.P., (1992), 'A Cross-Commodity Appraisal of Demand-Raising Research Benefits: Pork and Chicken in Australia', Journal of Agricultural Economics, Vol. 43(2): 243-247.

Waugh, F.V. (1929) Quality as a Determinant of Vegetable Prices. New York: Columbia University Press, Pp. 154.